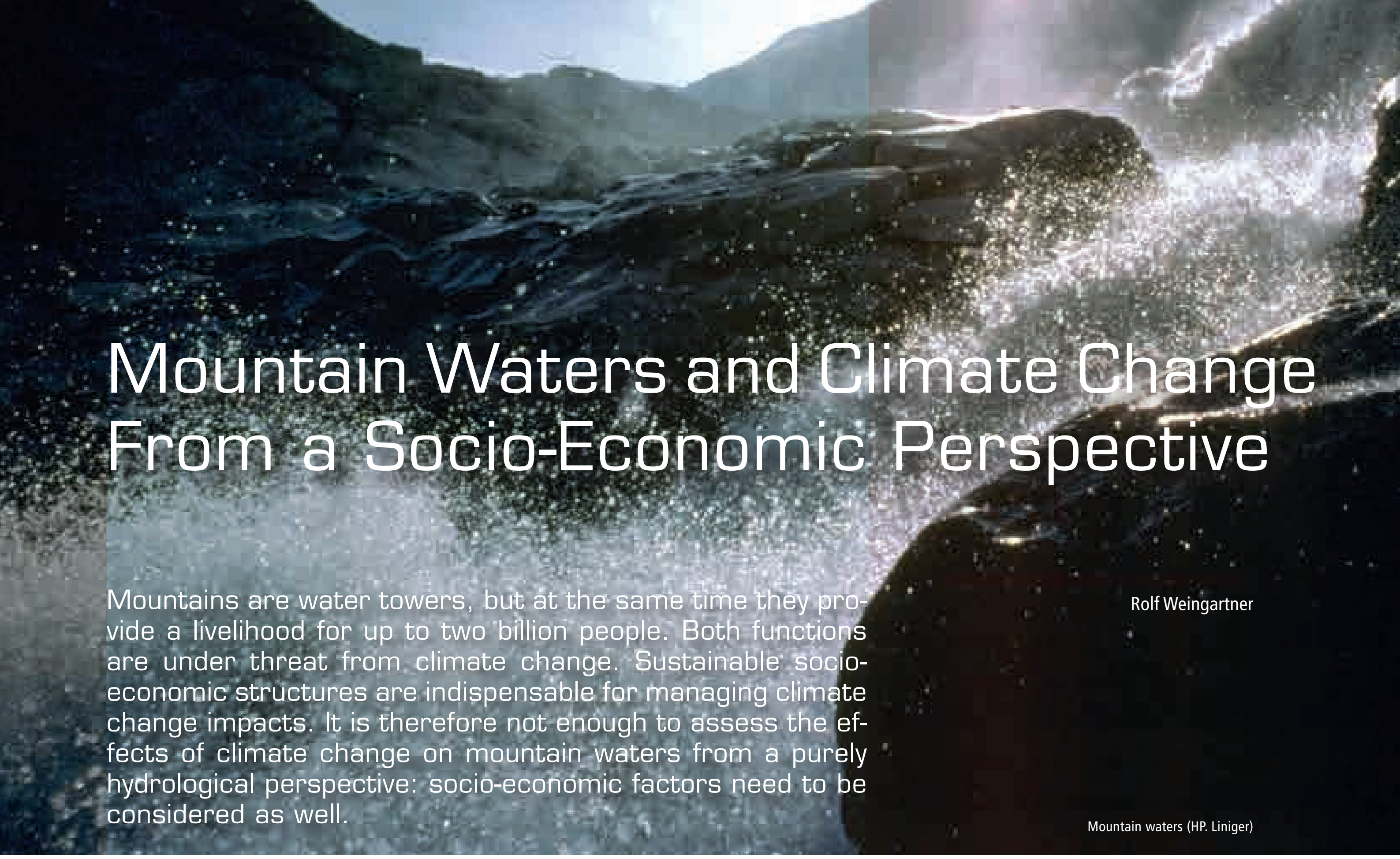


Mountain Waters and Climate Change From a Socio-Economic Perspective

Rolf Weingartner

Mountains are water towers, but at the same time they provide a livelihood for up to two billion people. Both functions are under threat from climate change. Sustainable socio-economic structures are indispensable for managing climate change impacts. It is therefore not enough to assess the effects of climate change on mountain waters from a purely hydrological perspective: socio-economic factors need to be considered as well.

Mountain waters (HP. Liniger)

Mountains are often described as water towers because they serve as a significant source of water for the adjacent lowlands [1]. Indeed, average runoff is approximately twice as high in mountain areas as in lowlands, except in the humid tropics. Nevertheless, this observation only scratches the surface. The assumption that higher precipitation rates and lower evapotranspiration rates cause mountains to generate more runoff than lowlands is correct (Figure 2.1). But a comprehensive hydrological assessment requires consideration of additional factors that can be summarized as water availability and water use (Figure 2.2). Changes in the climate and in socio-economic structures will alter these two parameters. They may evolve quite differently from region to region, given that mountain regions are highly diverse in terms of their environmental, cultural, societal and economic development. There are commonalities, however, and these commonalities are the focus of the following considerations.

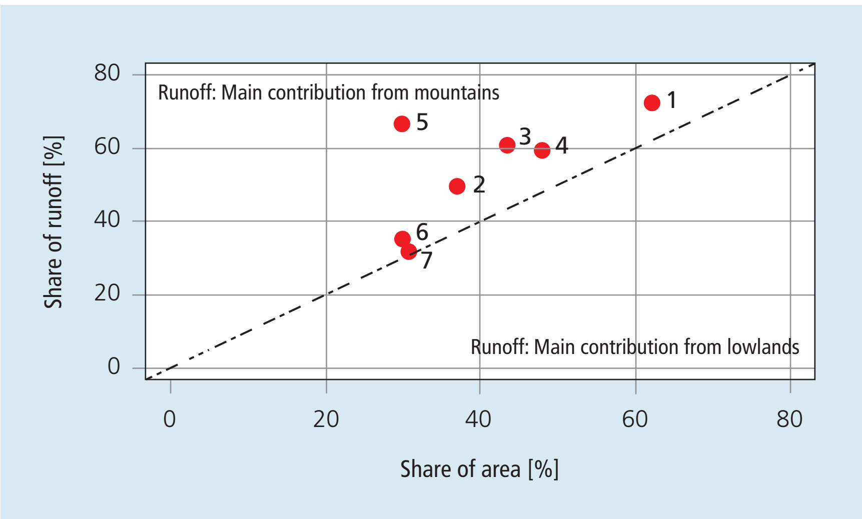
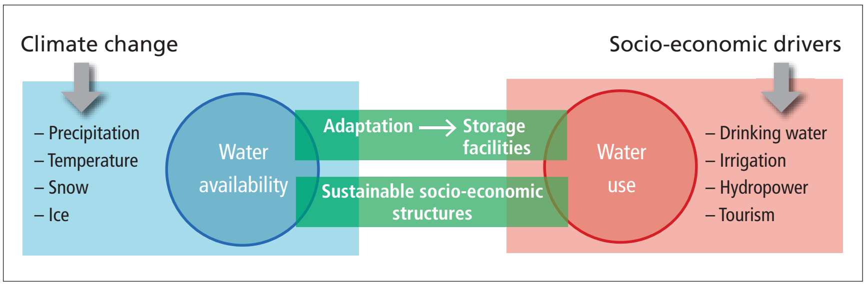


Figure 2.1. Mountains provide an above-average share of runoff in all zones except the humid tropics, as shown in this comparison between their shares of area and their shares of runoff in the different climatic zones. 1: polar, cold; 2: cool, 3: temperate; 4: semi-arid; 5: arid; 6: subtropical; 7: humid tropical. Data source: [2]

Water availability in transition

More than half of the world's drinking water originates from rivers and river-fed reservoirs. The shares of runoff that mountain regions contribute to these rivers are substantial: they range from 40 to 95 percent, depending on the region [2]. Runoff from mountainous watersheds is controlled mainly by precipitation and air temperature (Figure 2.2). While changes in precipitation amounts affect both annual and seasonal runoff volumes, temperature influences seasonal runoff behaviour by controlling snowfall and snowmelt. A rise in temperature usually leads to more runoff in winter, an earlier snowmelt in spring and, as a result, reduced runoff in summer (Figure 2.3). These changes are very likely to become a general trend, as climate models largely agree that temperatures will increase worldwide. The "only" remaining uncertainties concern the extent and the timing of the pre-



Policy messages

- Sound planning of adaptation measures on regional, national and transboundary levels is key, as the direction of change in hydrological systems is widely known. Adaptive measures such as implementing storage facilities have already been identified. Planning must be based on sufficient and sound evidence; but data are still lacking in many mountain regions.
- Adaptive measures are part of an overall strategy which also includes mitigation. The latter is much more effective than adaptation. Creating sustainable socio-economic structures must be part of the overall strategy: Without such structures, most measures will fail.

Figure 2.2. Interaction of mountain waters with water availability and water use (R. Weingartner)

Hydropower facility, Binntal, Switzerland (R. Weingartner)

"A total of 65 countries use over 75 percent of available water for food production, including China, Egypt and India, all of which rely heavily on mountain water." [6]

dicted temperature rise. By contrast, climate change effects on precipitation remain highly uncertain in terms of both the extent and the direction of change [3]. Figure 2.4 shows how annual precipitation might change in the world's mountain regions. It suggests that annual precipitation will increase in Asia, the northern Andes and the northern Rocky Mountains, whereas it will decrease in the Mediterranean basin, the southwestern United States of America, Central America and Southern Africa. Most climate models assume that the seasonal distribution of precipitation will not change much; but they predict a tendency towards drier dry seasons and wetter wet seasons. In conclusion, while snowmelt and glacier melt in the past mostly succeeded in compensating for summer dryness, we must now expect a strong reduction in summer runoff. This is one of the greater future challenges, especially because the demand for water is highest in summer.

Peak water in glaciers and the key role of snow

From a supraregional perspective, snow is a far more important source of water than glaciers are; this is due to its vast spatial extent. In Switzerland, for example, snowmelt contributes 40 percent of total runoff, whereas ice melt contributes only 2 percent. But in smaller and more glaciated catchments, a temperature-driven reduction in glacier mass is nevertheless hydrologically significant. It results in a temporary phase of increased summer runoff, a phenomenon referred to as "peak water". Its extent and duration depend primarily on the size of a glacier and the degree of glaciation in a catchment. A constantly retreating glacier will eventually shrink to a critical size where it can no longer deliver the same amount of water as before it began to retreat; this marks the end of the peak water phase with above-average runoff. Glaciated catchments in the tropics and several catchments in the European Alps have already reached or surpassed peak water, meaning that the glaciers in question will be unable to fulfil their important hydrological role in the near future [4].

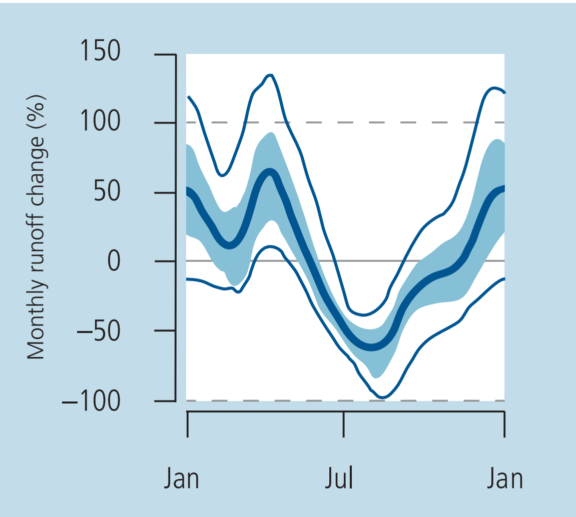


Figure 2.3. Mean relative monthly runoff change (in percent) of an Alpine basin in Switzerland between today and 2085 based on the medium emissions scenario A1B. Runoff is projected to increase in winter and decrease in summer. The mean over the uncertainty range (bold curve) is shown along with the standard deviation (shaded area) and the minima/maxima (thin curves). Source: [3]

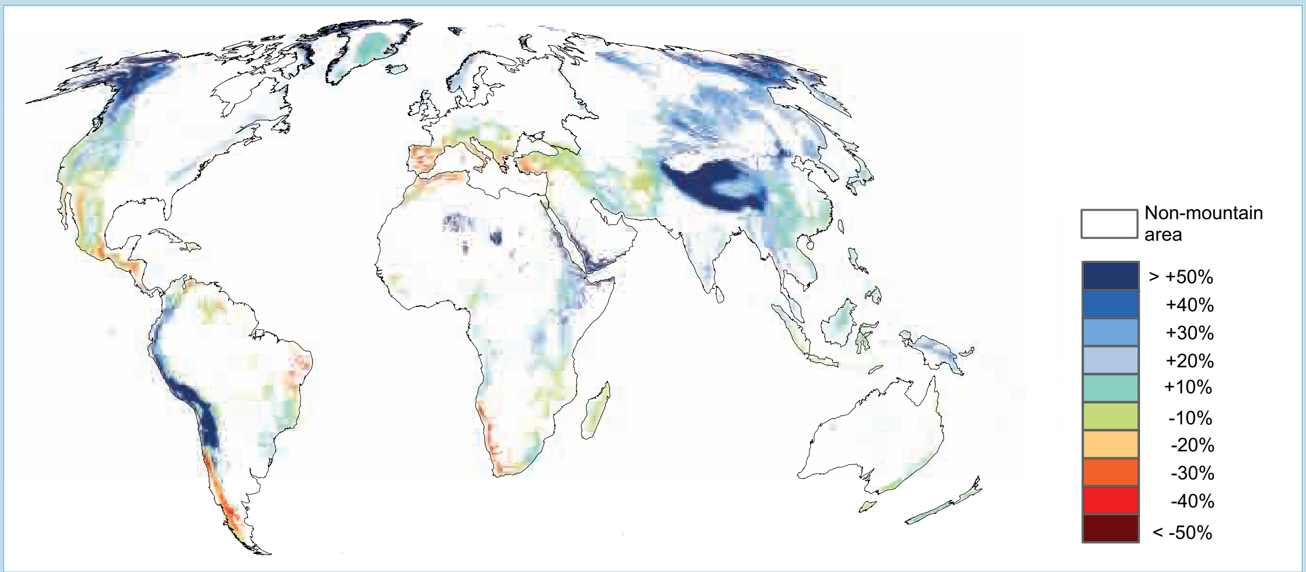


Figure 2.4. Percentage change of annual precipitation between 1950–2000 and 2070, based on the high emissions scenario RCP8.5. Precipitation data from IPCC (2014). Definition of mountain regions according to Kapos (modified). Courtesy of Andreas Heinimann and Lukas Wuersch (Centre for Development and Environment and Institute of Geography, University of Bern)

Demand for artificial storage facilities

We can say that climate change will lead to changes in snow and ice, and hence in seasonal runoff with lower flows particularly during summer seasons. At the same time, socio-economic pressure on mountain waters is constantly increasing, particularly in summer: More and more water is being needed for farming, energy production, industrial production, tourism and drinking. These opposing trends can be bridged by means of artificial multipurpose storage facilities. They can store the abundant winter runoff and thus compensate for reduced summer runoff while meeting the various users' water needs. In addition to building new storage facilities, existing single-purpose hydropower facilities can be transformed to multipurpose facilities for hydropower, irrigation, drinking water supply, flood control and other uses. Indeed, from today's perspective, this is one of the most important adaptation measures to be taken. It should be complemented by water-management schemes that regulate demand and set priorities for times of emergency.

Lake in the Andes (W. Buytaert)

The importance of looking at socio-economic factors

We estimate that over two billion people live in mountains and their surrounding lowlands [5], and this number will continue to increase. A case study in the Andes (Rio Santo, Cordillera Blanca) [4] reveals the consequences of this socio-economic pressure that is typical of many mountain regions: the demand for water in this region has drastically increased and will continue to increase. This is the result of population growth, combined with new irrigation systems that were installed in response to advantageous runoff conditions during the peak water phase. But once the peak dies down, supply constraints will be very likely (Figure 2.5). Situations like this are often significantly worsened by insufficient and badly maintained water infrastructure, increasing per capita water demand and urbanization.

A case study in the Swiss Alps (Crans-Montana, Valais) showed that the sustainability of a region's water supply depends on multiple factors: the manifestation of governance (can water infrastructure and management cover the population's needs?), ecological integrity (are the natural resources overused?), justice (do all have equal access to water?) and adaptive capacity (is society capable of reacting to change?). Most mountain regions are neglected border regions where poverty is widespread and a large majority of the population depends on subsistence agriculture; they do not fulfil these sustainability criteria. This is why an isolated focus on climate change is not enough. Ensuring sustainable socio-economic structures and good governance is the real key to managing the effects of climate change.

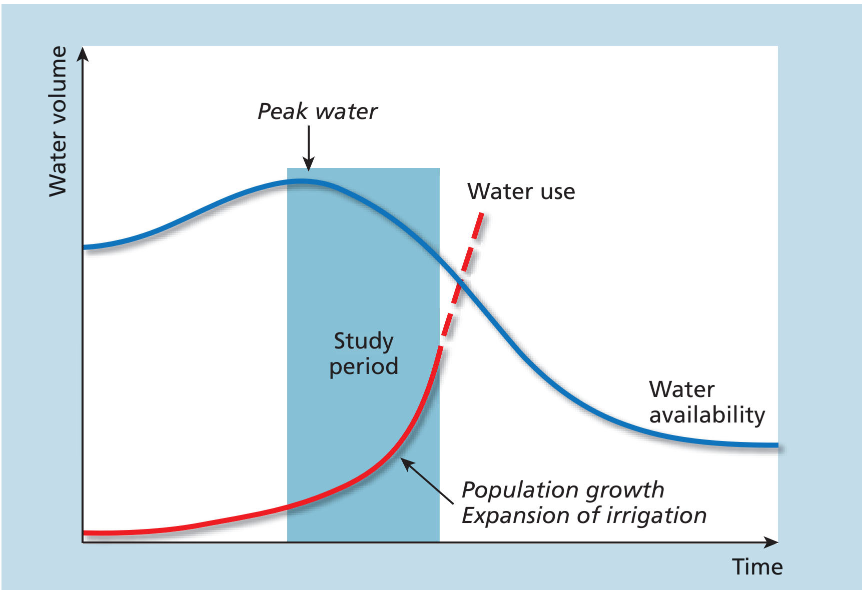


Figure 2.5. Water availability and water use in Rio Santo, Cordillera Blanca (Andes). Based on [4]


Mekong River, China (HP. Liniger)